

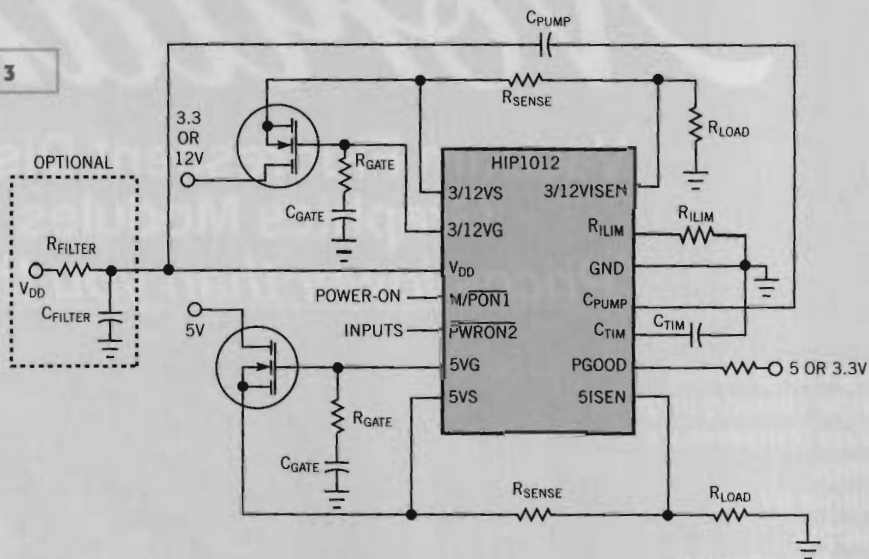
resets the controller. For power-up control of supply sequencing, you can program the two MOSFETs' turn-on ramps by selecting suitable values for C_{GATE} .

R_{GATE} is a 10 to 200 Ω resistor that prevents current oscillation. As usual, an internal charge pump provides gate drive (17.4V for a 12V bus, 11.4V for 3.3 or 5V) for the MOSFETs. V_{DD} is the 12V supply for the controller. You use the optional decoupling filter if the 12V chip supply also powers the load; if you use a dedicated chip supply, the network may be unnecessary. The HIP1012 costs \$4.85 (1000). Harris offers evaluation boards for both general-purpose and RAID applications.

Apropos of multiple supplies, Linear Technology's LTC1643 controls hot-swap operations for *four* power rails: -12 , 3.3 , 5 , and 12V (**Figure 4**). Intended for PCI-bus (CompactPCI) applications, the IC provides on-chip switches for the -12 and 12V rails and controls external n-channel MOSFETs for the 3.3 and 5V rails. R_1 and R_2 provide current-fault detection; R_3 and C_1 provide current control-loop compensation. After the external pass transistors turn on, the current in each transistor increases until it reaches its current limit. Each supply then powers up at the rate $dV/dt=50\text{ }\mu\text{A/C}_1$, or at a rate determined by the current limit and the load capacitance, whichever is slower. The IC ignores current-limit faults when the timer pin ramps up toward 0.9V less than the 12V input level.

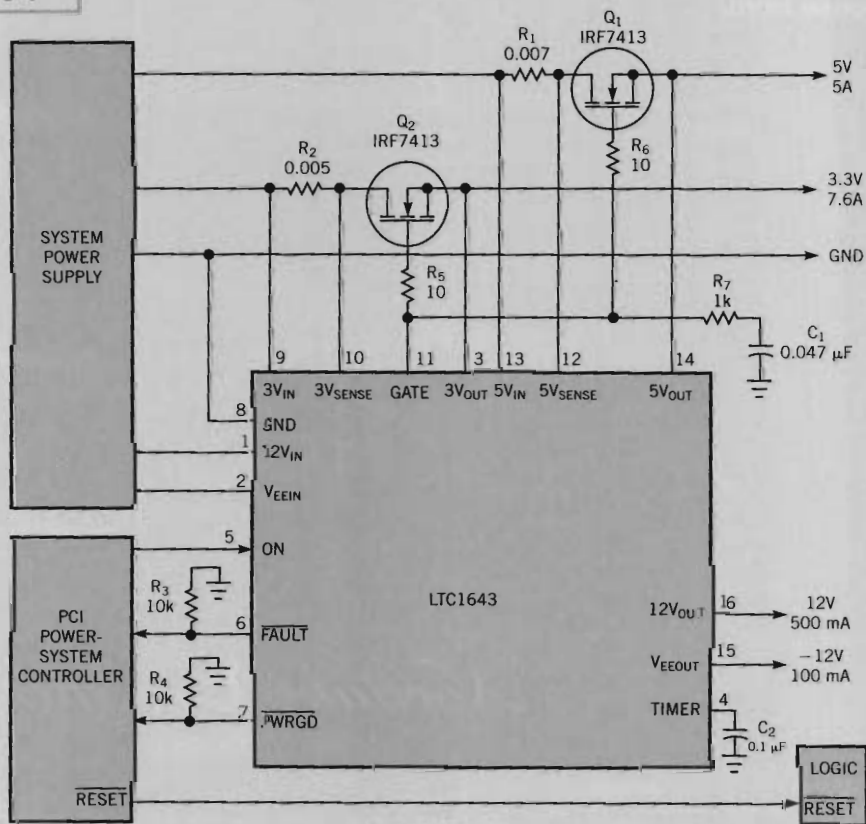
The LFC1643 features fold-back current limiting. The low-value current-sensing resistors in series with the external MOSFETs set the current limits for these supplies. For a 0.005Ω resistor in the 3.3 or 5V line, the current limit is 10.6A, folding back to 1.5A for a short

Figure 3



Live insertion/removal is a must in RAID systems; the HIP1012 from Harris Semiconductor provides hot-swap protection for the disk-drive power buses in these redundant systems.

Figure 4



PCI applications can use as many as four power buses; Linear Technology's LTC1643 provides hot-swap protection for all four buses.

circuit. For a 0.007Ω resistor, the figures are 7.6 and 1.1A, respectively. The preset current limit for the internal 12V switch is 850

mA, folding back to 250 mA; for the -12V switch, the respective values are 450 and 160 mA. The fold-back capability allows

the controller to power boards with varying capacitive loads without incurring nuisance trips of the IC's circuit breakers. The

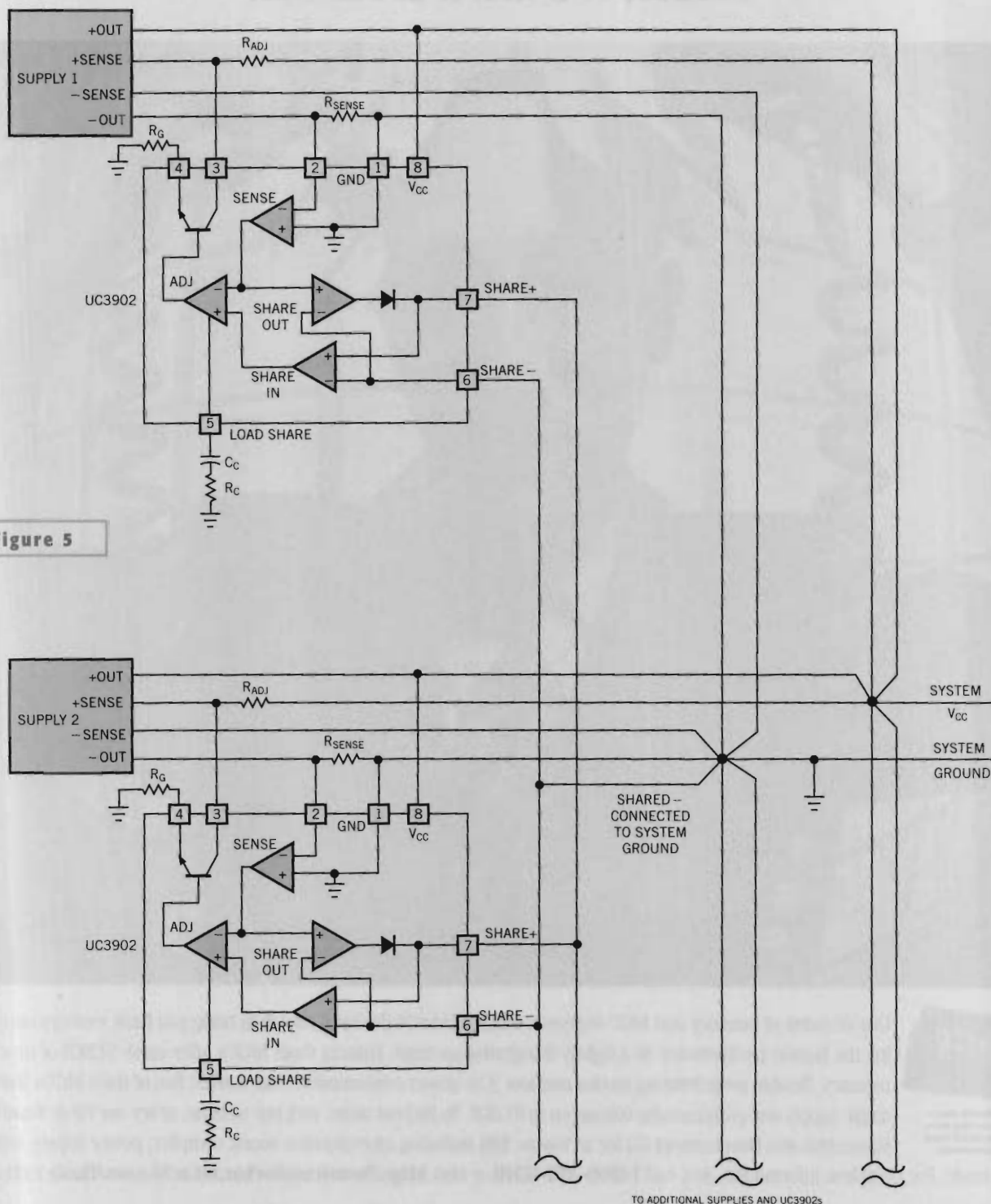
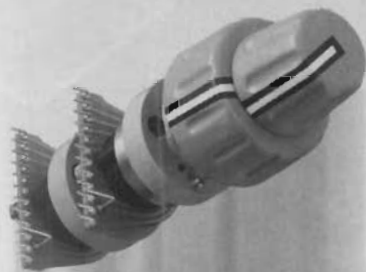


Figure 5

Using the output-voltage-sense line available on many power-supply modules, Unitrode's UC3902 load-share controller equalizes the current contributions from multiple, parallel-connected supplies.



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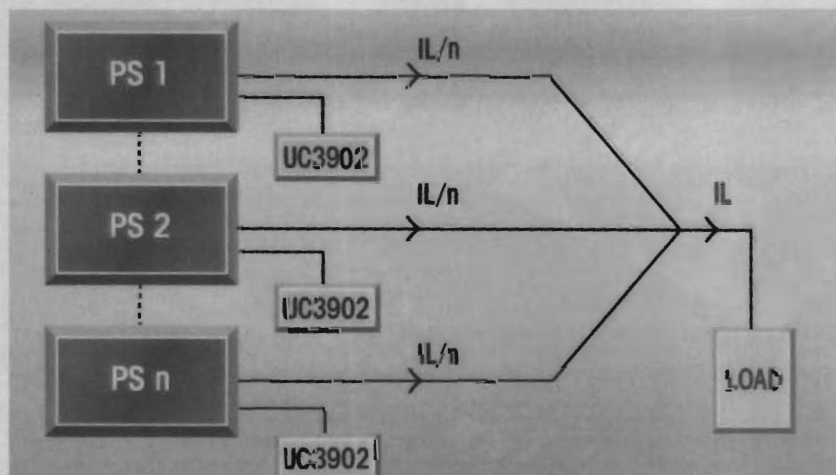
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A handful of UC3902 load-share ICs from Unitrode can prevent multiple supplies from oversupplying or undersupplying their share of load current.

LTC1643 costs \$4.25 (1000) and comes in two versions: The LTC1643H targets PCI applications that control hot swapping on the motherboard; the LTC1643 controls hot swapping on the PCI card. **Reference 2** gives a wealth of application information for the LTC1643.

Texas Instruments calls its hot-swap controllers "power-interface switches." The \$1.65 (2000) TPS2211 single-slot switch for a PC (PCMCIA) Card has 90-m Ω switches for the 3.3 and 5V power supplies. Break-before-make operation provides hot-swap capability. The \$3.22 (2000) TPS2206 provides similar capabilities for controlling two PC Cards. Its three-lead serial interface is compatible with CardBus controllers. The \$3.02 (2000) TPS2205 two-slot controller is similar to the TPS2206, but it uses an interface that is compatible with IC-based PC Card controllers available from myriad manufacturers. Finally, TI's 88-cent (2500) TPS2014 and 88-cent (2500) TPS2015 USB hub controllers provide 95m Ω MOSFET switches with controlled rise and fall times that protect USB systems from hot-swap and transient damage.

SHARE AND SHARE ALIKE

It is often beneficial to connect multiple power supplies in parallel to increase total power capacity, achieve redundancy, or both. **Reference 3** discusses some of the issues involved in configuring redundant multiple-supply systems. For various reasons, it is important that all the supplies share the load current as equally as possi-

ble. The sidebar "Current sharing and fault tolerance," describes several current-sharing schemes. Most power-supply manufacturers offering products for parallel connection build the current-sharing mechanisms into the supplies, often with hot-swapping capability. If you wish to configure your own multiple-supply systems, several load-sharing ICs offer an easy and efficient way to optimize load sharing among the supplies.

The UC3902 from Unitrode Corp is an eight-pin device that balances the current drawn from independent, parallel-connected power supplies. It effects load sharing by adjusting each supply's output current to a level that is proportional to the voltage on a shared bus. **Figure 5** shows two UC3902s connected to their respective supplies in a multiple-supply system. The master supply, designated as the supply that regulates to the highest voltage, drives the share bus with a voltage that is proportional to its output current. The UC3902 trims the output voltage of the other paralleled supplies so that each supply supports its share of the load current. The currents need not necessarily be equal. By appropriately scaling the current-sense resistor R_{SENSE} , you can connect supplies with different output-current capabilities so that each supply provides the same percentage of its output-current capability for a given load.

The UC3902 is compatible with power supplies that incorporate remote output-voltage sensing. The IC trims the supply's output by injecting a small current into the

output-voltage sense line. The differential share bus maximizes noise immunity and accommodates voltage drops in each power supply's ground-return line. **Reference 4** and the UC3902 data sheet detail how to determine the component values in **Figure 5**. The UC3902 costs \$1.62 (1000). An older sibling of Unitrode's UC3902, the UC3907, comes in a 16-pin DIP or SOIC, or a 20-pin PLCC and offers optocoupler-driving capability.

Vishay Siliconix takes a different approach to current sharing with its Si9143CG buck-controller IC. This synchronous controller targets point-of-use dc/dc conversion in servers and desktop computers in which shared supplies can reduce stress on power-supply components and thereby increase system reliability. The IC ensures equal current sharing by connecting the PWM and sync pins to make multiple controllers' duty cycles identical. The sync pin forces all the controllers to simultaneously start their duty cycles; the PWM

pin forces the controllers to simultaneously finish their duty cycles. Thus, all controllers run at the same frequency and phase; they can also run from the same power bus and deliver power to the same output bus. Operating as fast as 1 MHz, the Si9143CG ensures equal current sharing to within 1%. The device costs \$1.80 (25,000).

Issues such as ease of use, service accessibility, and reliability make both hot swapping and current sharing important considerations in system design. ICs that painlessly help you realize these functions make it possible for you to ignore these power-supply issues and devote your efforts to more productive tasks. □



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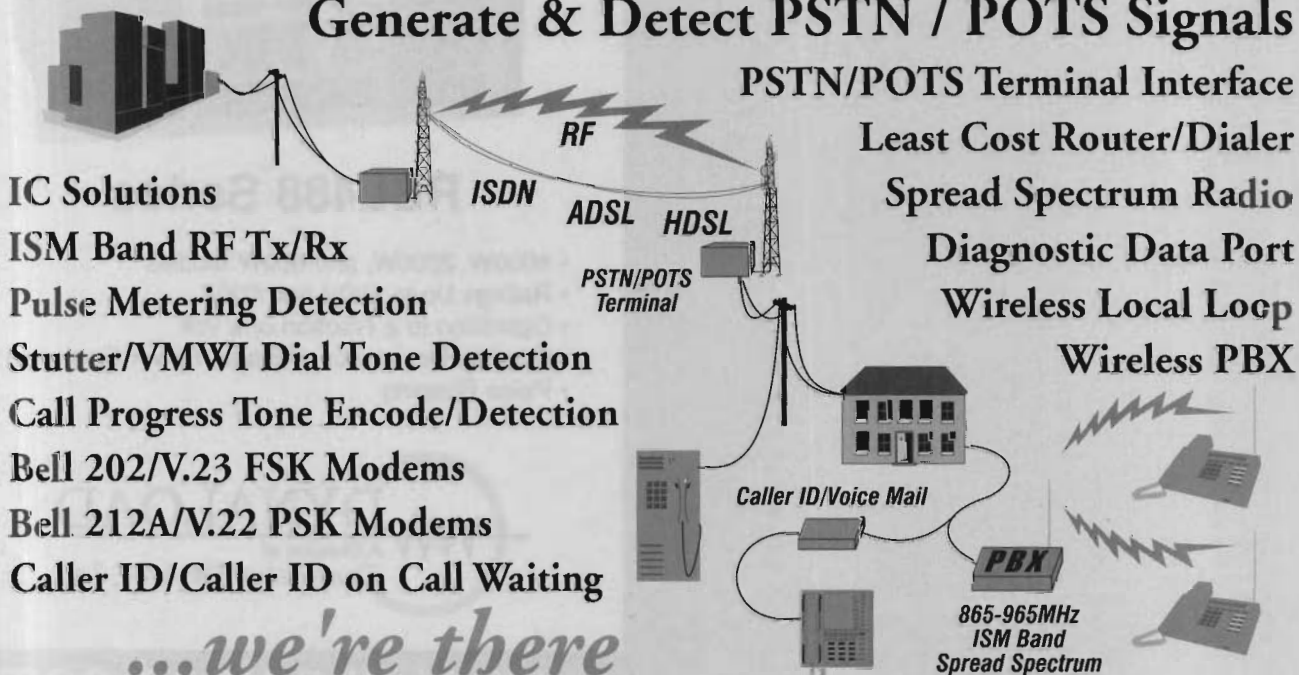
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